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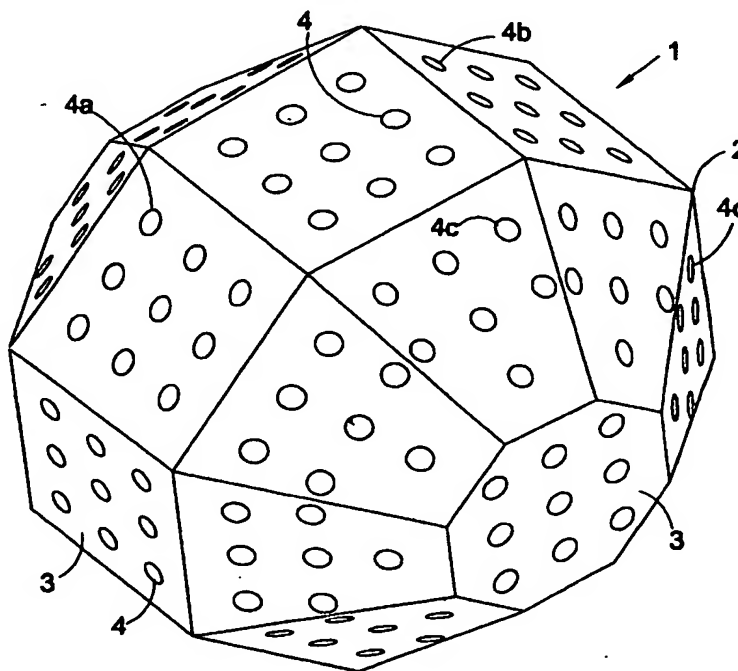
(43) International Publication Date
7 June 2001 (07.06.2001)

PCT

(10) International Publication Number
WO 01/41517 A1

- (51) International Patent Classification⁷: **H05K 1/00**
- (21) International Application Number: **PCT/GB00/04610**
- (22) International Filing Date: **1 December 2000 (01.12.2000)**
- (25) Filing Language: **English**
- (26) Publication Language: **English**
- (30) Priority Data:
9928257.6 1 December 1999 (01.12.1999) **GB**
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- (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- Published:**
— With international search report.
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **IMPROVEMENTS IN OR RELATING TO CIRCUIT BOARDS**



(57) Abstract: A circuit structure (1) is described which is based on a solid three-dimensional electrically non-conductive body (2) which can be polyhedral or pyramidal. At least two faces (3) define an aperture (4) with a conduit (5) being provided through the body (2) connecting the apertures (4). The conduit (5) is filled with a conductive material (6), e.g. ink or wire, to provide an electrical connection between the apertures (4). Electrical components (12) on different faces (3) may be connected through the apertures (4). Embodiments of the invention are described.

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IMPROVEMENTS IN OR RELATING TO CIRCUIT BOARDS

This invention relates to improved printed circuit boards (PCBs).

PCBs and methods for the production thereof have been available for a number of years. Over these years the use of PCBs in electronic equipment has markedly increased until today they are found in a large variety of equipment for example household equipment, such as televisions and washing machines. The PCBs are used in this type of equipment to help provide a broad range of functions and programming in an attempt to fulfil the demands of today's society. The basic purpose of the PCB is to provide discrete components such as resistors, capacitors, microprocessors, silicon chips, and the like with a stable base and to provide the electrical connection between the components on the board.

A typical PCB will comprise a substrate of electrically insulating material, for example a sheet of reinforced fibreglass with a polyester resin typically called FR-4, onto which is formed a circuit pattern of electrically conducting material such as tin or copper.

In some applications in order to reduce the size of the boards various layers of PCB are packed on top of each other and up to 12 or more layers onto each of which a circuit pattern is formed. The layers are laminated together and the circuit patterns between each layer are connected by a metal connector (known as vias or microvias). The production of such multiple layer boards is both time consuming and involves many complex stages requiring different equipment thereby resulting in an expensive production process. The resulting PCBs have a 2-dimensional working surface and this applies limitations on what components can be mounted on the 2-dimensional board and thus the tasks that can be carried out by the components.

Additionally, if a fault occurs in one of the circuits in a layer of the PCB, it is very difficult to

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detect although it could be repaired with jumper wires, in some cases there may be so many faults which might result in the entire board being discarded. This can be costly and also lead to further damage to the circuit pattern. Furthermore, should maintenance be required to the PCB, this must be done by skilled personnel as damage may occur to the conductive tracks on the surface of the PCB.

The present invention aims to provide a circuit structure that overcomes or at least mitigates the problems associated with the known PCBs.

According to a preferred embodiment of the invention, there is provided a circuit structure having a three-dimensional (3-D) body, the surface of said 3-D body comprising a plurality of two-dimensional (2-D) faces, wherein at least two of the 2-D faces define at least one aperture, a conduit being providing through the 3-D body between the two apertures, the conduit having an electrically conductive material disposed therein for providing an electrical connection through the conduit.

Preferably, the conduit is filled with an electrically conductive material.

Alternatively, a wire is disposed within the conduit.

Preferably, each 2-D face defines a plurality of apertures. Preferably, a plurality of conduits are provided within the 3-D body, each conduit being provided between an aperture in one 2-D face and an aperture in another 2-D face.

Additionally, connectors may be provided in at least one aperture of the 3-D body to enable at least one further 3-D body to be connected thereon.

Preferably, the 3-D body is an electrically non-conductive high temperature resistance material.

Preferably, the electrically non-conductive material is a thermoplastic or thermosetting polymeric material.

Conveniently, at least one electrical component is

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positioned within at least one conduit.

Preferably, the electrical component is held in position within the conduit by electrically conductive material.

5 Preferably, the electrically conductive material is an electrically conductive ink.

Alternatively, the electrically conductive material is an electrically conductive adhesive.

Preferably, the 3-D body is a polyhedron.

10 Additionally, the 2-D faces may be of a polygonal form.

Preferably, at least one electrical component is mounted on at least one 2-D face. Preferably, the electrical component is electrically connected to at least one filled conduit by way of connection through the appropriate aperture.

15

Preferably, the 3-D body forms a circuit structure. Additionally, at least one conduit may be formed internally in the 3-D body connecting at least two other conduits together.

20

Preferably, at least one conduit is provided through the body for providing cooling fluid.

According to another aspect of the present invention there is provided a circuit structure comprising a polyhedral body, at least two surfaces of which define an aperture therein, a conduit being provided through the body between the two apertures, the conduit being filled with an electrically conductive material for providing an electrical connection through the conduit.

25

Preferably, each face of the polyhedral body is provided with a plurality of apertures.

30

Advantageously, a plurality of conduits are provided within the body, each connecting an aperture in one surface of the body to an aperture in another surface of the body.

35

Conveniently, connectors are provided in the apertures of one surface of the body to enable a further body to be attached thereon.

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Conveniently, the polyhedral body is formed of high temperature resistant thermoplastics or thermosetting polymeric materials such as PTFE, TEFLON (registered trade mark of E.I. du Pont de Nemours and Company),
5 polyimides or epoxides or any other suitable material.

Advantageously, in some application an electrical component may be located within a conduit.

Advantageously, the electrical component is held in position within the conduit by conductive material.

10 Advantageously, the conductive material is conductive ink or conductive adhesive.

One embodiment of the present invention will now be described with reference to the accompanying drawings in which:

15 Figure 1 is a perspective view of a polyhedral circuit structure in accordance with a preferred embodiment of the present invention;

Figure 2 is a perspective view of the body of Figure 1 wherein the conduits within the body are filled with
20 conductive material;

Figure 3 is a perspective view of the body of Figure 1 with a surface mounted component applied thereto;

Figure 4 is a perspective view of the body of Figure 3 showing through hole components with the appropriate
25 through holes;

Figure 5 is a schematic view of an apparatus for drilling conduits in the body of Figure 1;

Figure 5a is a schematic view of an apparatus for filling the conduits in the body of Figure 1;

30 Figure 6 is a perspective view of one method of connecting two circuit structures together;

Figure 7 is a perspective view of an alternative method of connecting two circuit structures together; and

35 Figure 8 is a part cross-sectioned perspective view of the body of Figure 1 with an electrical component located within a conduit in the body.

Turning now to the Figures there is shown a circuit

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structure 1 comprising a three-dimensional (3-D) polyhedral body 2 formed of any electrically non-conductive material such as for example PTFE, TEFLON (registered trade mark of E.I. du Pont de Nemours and Company), polyimides or epoxides or any other suitable material. The body may be moulded or formed by way of any suitable known method.

The body is shown in Figure 1 as being 26 sided although the body may have any number of surfaces 3 depending upon the intended use. The shape and size of each surface will be dependent on the shapes and sizes of the components to be mounted on that surface.

Apertures 4 are defined in each surface of the body. These apertures could be regarded as pads in conventional PCB's and will also serve the same purpose. In some surfaces nine apertures are shown and in others seven apertures are shown. In practice, the number of apertures provided in each surface may be selected to be the same or may alternatively be different.

Conduits 5 are provided through the body, conduit 5 being provided between apertures 4 of different surfaces 3. For example, in Figure 1, one conduit may be provided between apertures 4a and 4b and another conduit may be provided between apertures 4c and 4d. The conduits 5 may be formed by a method to be described below.

Once the conduits 5 are formed, they are filled with an electrically conductive material 6. This may be a commercially available conductive ink such as ORMET ink as described in WO93/06943. The body 2 is then placed in a curing oven in order to cure the ink in position within the conduits.

As shown in Figure 3, surface mounted components 12 may be soldered onto the filled and cured conduits 5 at apertures 4 in a surface 3 of the body. For example, a resistor 12 may be mounted between two apertures 4 on a surface 3 thereby connecting the conduits 5 that terminate at those apertures together.

In order to mount a through hole component in the apertures, a portion of the cured conductive material 6 is drilled from each of the apertures 4 and the legs of the component are inserted into the resulting holes 11 within the filled apertures 4. The holes 11 are then filled with further conductive material 6 of any suitable conductive adhesives and the body 2 is placed in a curing oven to cure the component 12 in position.

Figure 5 is a schematic illustration of an apparatus for forming the conduits 5 through the body 2. The body is held in a mounting device 8 upon which it can be rotated. A drill or laser 9 is mounted above the body. The body can be rotated or allowed to move in the mounting device 8 such that any surface 3 of the body 2 can be brought into registry with the drill or laser 9 in the required position to form a conduit 5 between one surface and another. The movement of the mounting device 8 and the drill or laser 9 may be controlled by a microprocessor (not shown) in order to form the required conduits.

In the event that a laser is used to form the conduits, it would be designed to work in conjunction with a wave guide and an appropriate fibre optic cable. The laser may be either a pulsed type or any other appropriate laser used for drilling holes in PCBs.

Further conduits 5 may be formed within the body 2 itself by passing a light beam through a fibre optic cable (not shown) with the aid of an appropriate wave guide emitted from the free end thereof along a conduit 5 to the required position. The laser beam is then focussed onto the wall of the conduit to cut through the wall forming a further conduit connecting two other conduits together.

Figure 5a shows a schematic view of an apparatus for filling the conduits in the body with conductive material 6. This apparatus may be incorporated into the apparatus for forming the conduits as described above. A reservoir

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13 of conductive material may be held within the apparatus and the body is rotated in the mounting device 8 to bring the apertures of the required conduits into registry with an outlet 14 of the reservoir.

5 Figure 6 illustrates one example of how two or more circuit structures 1 according to the present invention may be connected together to increase the surface area available and also to connect the conductive conduits 5 of one structure to another.

10 After the conduits 5 have been filled with conductive material 6 and the body 2 has been placed in the curing oven, selected apertures 4 on a surface 3 of the two bodies are drilled out and metal pins 10 are inserted into the resulting apertures 11. The apertures
15 11 are then filled with further conductive material 6 and the bodies are placed in a curing oven to cure the conductive material thereby locking the two bodies together.

20 In Figure 6, the bodies are connected in a side-by-side relationship, whereas in Figure 7 they are shown in an exploded view to be connected directly one above the other. Any number of surface structures may be connected together in these ways.

25 In the foregoing description the components applied to the circuit structure are described as surface mounted or through holes, however it is envisaged that components may also be located within the conduits 5 passing through the body 2 itself. This is shown in Figure 8 of the drawings. In this instance, the component 12, for
30 example a resistor, is pushed into the conduit before the conduit 5 is filled with conductive material 6.

35 The diameter of the component 12 is chosen to be close to that of the conduit 5 so that the component is a tight fit within the conduit. Conductive material 6 is then fed into each end of the conduit, through the respective apertures 4 in the surfaces of the body 2 and the body is placed in a curing oven to cure the

conductive material.

In some circumstances, the conductive material may be replaced by wires running through the conduits. These wires will terminate at the apertures and could be held in position by any conductive material bonded to it.

In providing a circuit structure in accordance with the present invention, the conductive tracks applied on the surface of a standard PCB are formed within the body, thereby reducing potential damage to the circuits formed in the body. The 3-D dimensional configuration of the structure allows a solid, compact circuit structure to be provided that can replace large PCB present in many electrical devices currently available such as computers.

As the bodies are easily connected together, the circuits therein can be simply expanded or alternatively can be separated without the problems associated with dismantling a laminated structure such as a PCB. Also this could enable the creation of separate functions within a single circuit. For example power circuits could be placed on a separate structure from discrete component circuits.

Although the preferred embodiment discloses a polyhedral shaped body, it can be appreciated that the 3-D body may take a form which does not conform to a polyhedral structure (i.e. it has fewer than six faces). For example, the 3-D body may take a pyramidal form, having four or five faces, the advantage of this being that pyramidal bodies would nest together in a compact way.

The present invention provides a low cost, low maintenance structure that can be used to replace PCBs wherever they are currently used.

The present invention could also enable the creation of complex circuitry such as those found in parallel computing. If parallel computing is required for example by the mounting of several processors on different faces of the structure, further channels could be provided,

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through the body for circulating cooling fluid to the structure thereby enabling the cooling of the processors from inside the body. The cooling could be achieved by the use of appropriate pumping or fluid circulating mechanisms.

5

CLAIMS

1. A circuit structure having a three-dimensional (3-D) body, the surface of said 3-D body which comprising a plurality of substantially two-dimensional (2-D) faces wherein at least two of the 2-D faces define at least one aperture in each respective face, a conduit being
5 provided through the body between the two apertures, the conduit having an electrically conductive material disposed therein for providing an electrical connection through the conduit.
- 10 2. A circuit structure as claimed in claim 1 wherein the conduit is filled with an electrically conductive material.
3. A circuit structure as claimed in claim 1 wherein a wire is disposed within the conduit.
- 15 4. A circuit structure as claimed in any of the preceding claims wherein each 2-D face of the 3-D body defines a plurality of apertures.
5. A circuit structure as claimed in any of the preceding claims wherein a plurality of conduits are
20 provided within the 3-D body, each conduit being provided between an aperture in one 2-D face of the 3-D body and an aperture in another 2-D face of the 3-D body.
6. A circuit structure as claimed in any of the preceding claims wherein connectors are provided in at
25 least on aperture of the 3-D body to enable at least one further 3-D body to be connected thereon.
7. A circuit structure as claimed in any of the preceding claims wherein the body is formed of an electrically non-conductive high temperature resistant
30 material.
8. A circuit structure as claimed in any of the preceding claims wherein the electrically non-conductive material is a thermoplastic or thermosetting polymeric material.
- 35 9. A circuit board as claimed in any of the preceding claims wherein at least one electrical component is

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positioned within at least one conduit.

10. A circuit structure as claimed in claim 9 wherein the electrical component is held in position within the conduit by electrically conductive material.

5 11. A circuit structure as claimed in any of the preceding claims wherein the electrically conductive material is electrically conductive ink.

12. A circuit structure as claimed in any of the preceding claims wherein the 3-D body forms a polyhedron.

10 13. A circuit structure as claimed in any of the preceding claims wherein the 2-D faces are of a polygonal form.

14. A circuit structure as claimed in any of the preceding claims wherein at least one electrical
15 component is mounted on at least one 2-D face of the 3-D body.

15. A circuit structure as claimed in claim 12 wherein the electrical component is electrically connected to at least one filled conduit by way of connection through the
20 appropriate aperture.

16. A circuit structure as claimed in any of the preceding claims wherein the 3-D body forms a circuit structure.

17. A circuit structure as claimed in any of the
25 preceding claims wherein at least one conduit is formed internally in the 3-D body connecting at least two other conduits together.

18. A circuit structure as claimed in any of the preceding claims wherein at least one conduit is provided
30 through the body for providing cooling fluid.

19. A circuit structure comprising a polyhedral body at least two surfaces of which define an aperture therein, a conduit being provided through the body between the two apertures, the conduit being filled with an electrically
35 conductive material for providing an electrical connection through the conduit.

20. A circuit structure as claimed in claim 19 wherein

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each face of the polyhedral body is provided with a plurality of apertures.

21. A circuit structure as claimed in claim 20 or 21 wherein a plurality of conduits are provided within the polyhedral body, each conduit connecting an aperture in one surface to an aperture in another surface.

22. A circuit structure as claimed in any one of claims 19 to 21 wherein connectors are provided in the apertures of one surface of the body to enable a further body to be attached thereon.

23. A circuit structure as claimed in any one of claims 19 to 22 wherein the polyhedral body is formed of a thermoplastic or thermosetting polymeric material.

24. A circuit structure as claimed in any one of claims 19 to 22 wherein the polyhedral body is formed of a polyimide or an epoxide.

25. A circuit structure as claimed in any one of claims 19 to 24 wherein an electrical component is located within a conduit.

26. A circuit structure of claim 25 wherein the electrical component is held in position within the conduit by means of an electrically conductive material.

27. A circuit structure of any one of claims 19 to 26 wherein the electrically conductive material is conductive ink.

28. A circuit structure of any one of claims 19 to 26 wherein the electrically conductive material is a conductive adhesive.

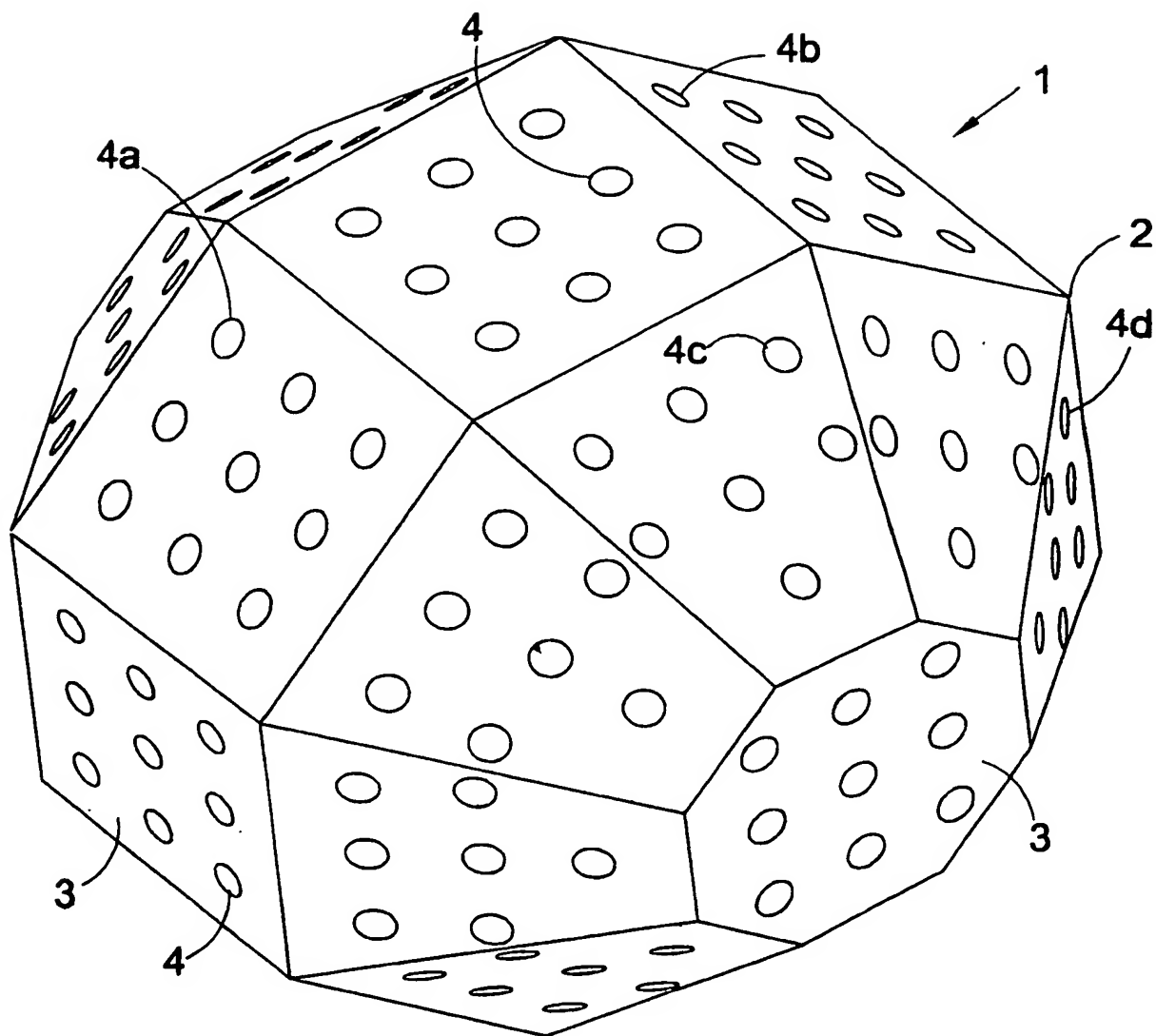


Fig.1

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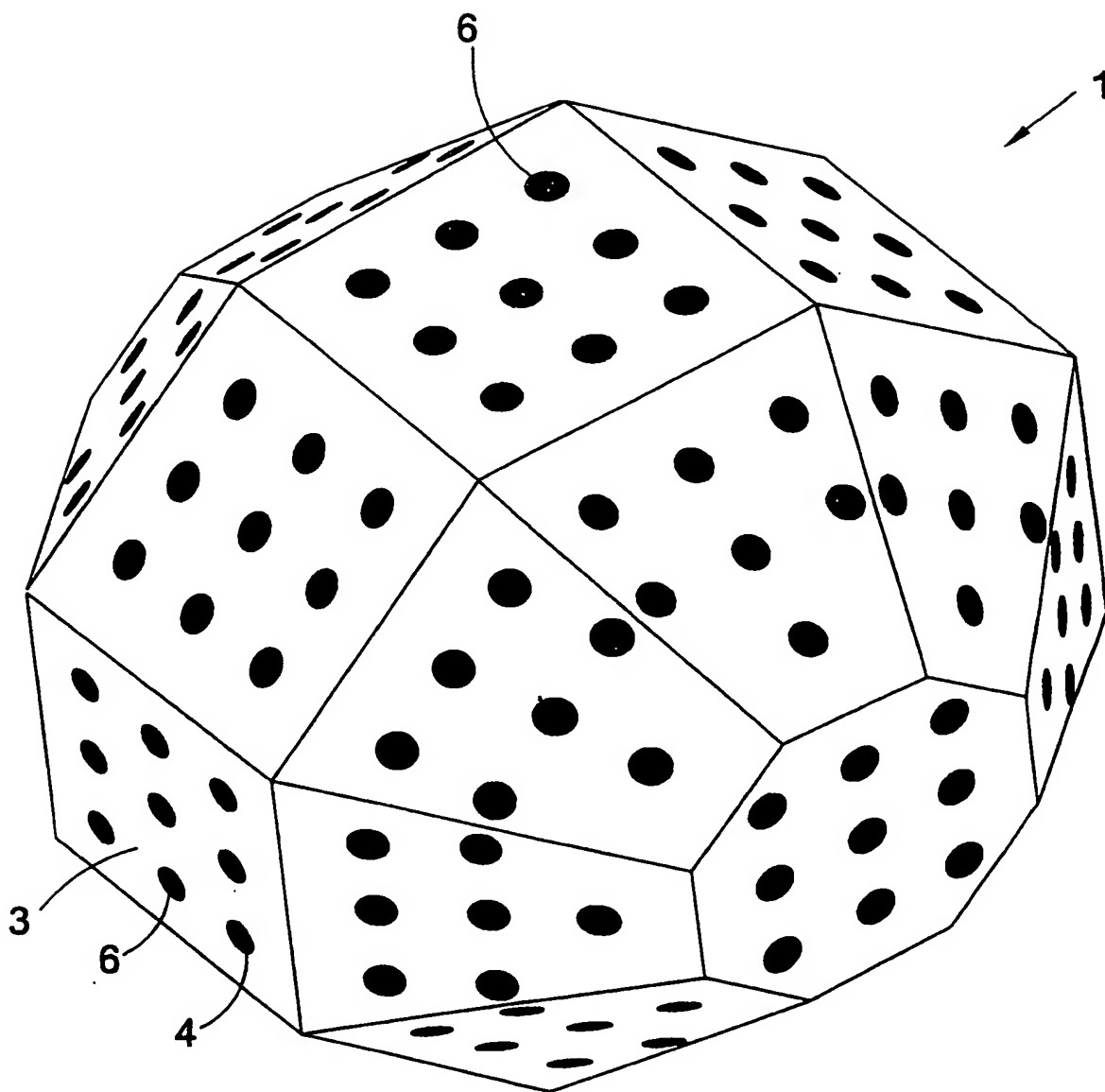


Fig.2

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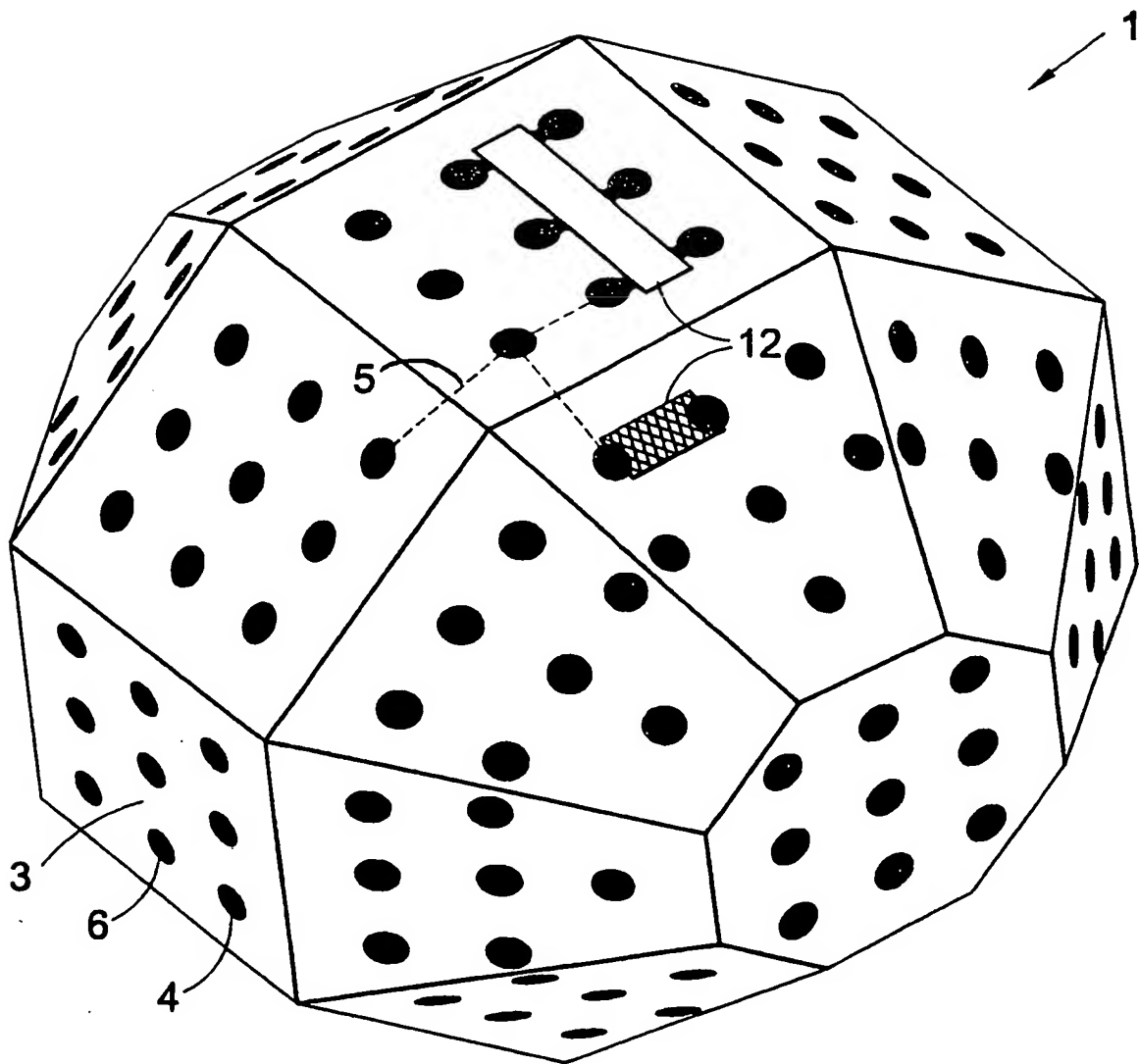


Fig.3

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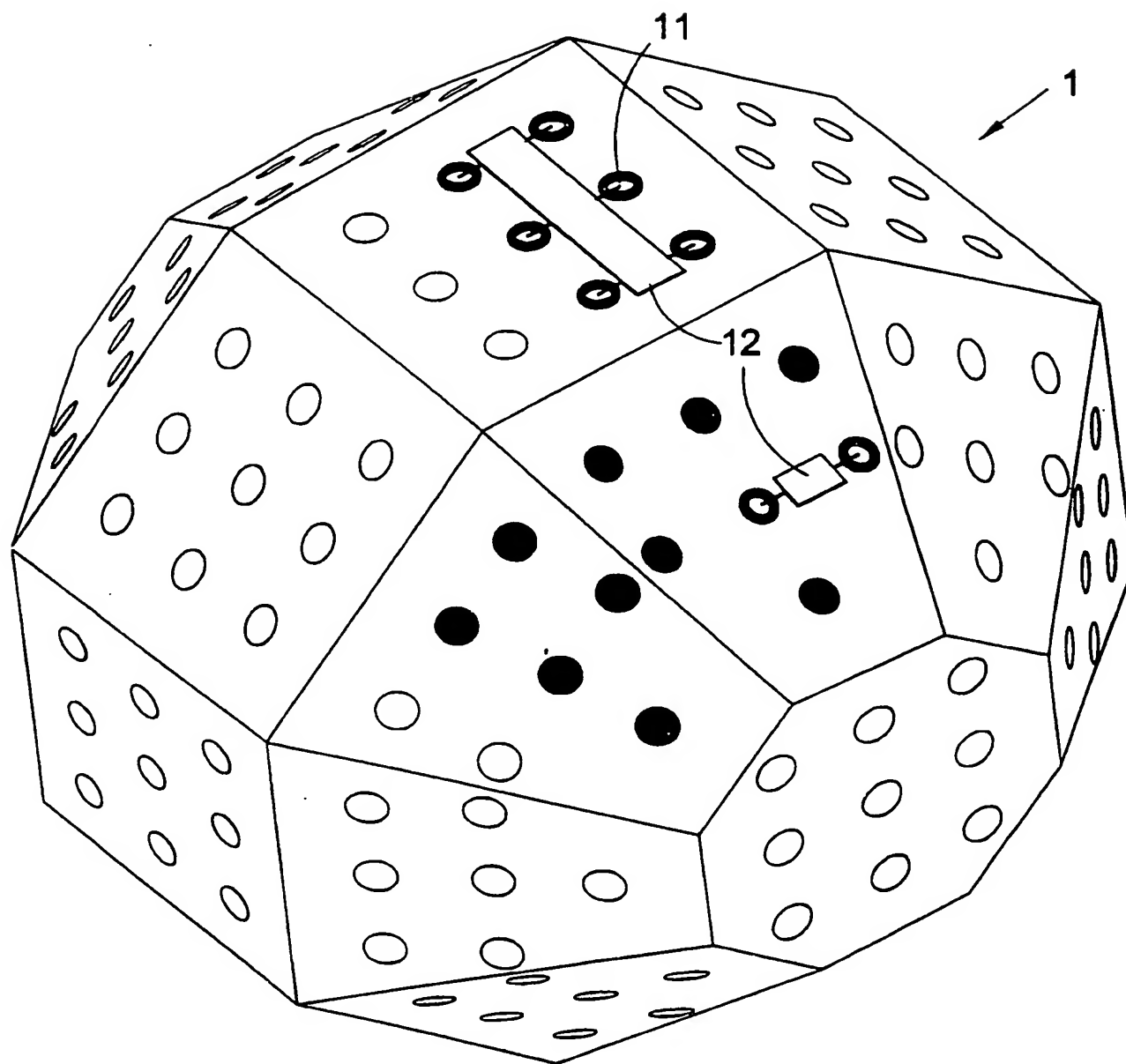


Fig.4

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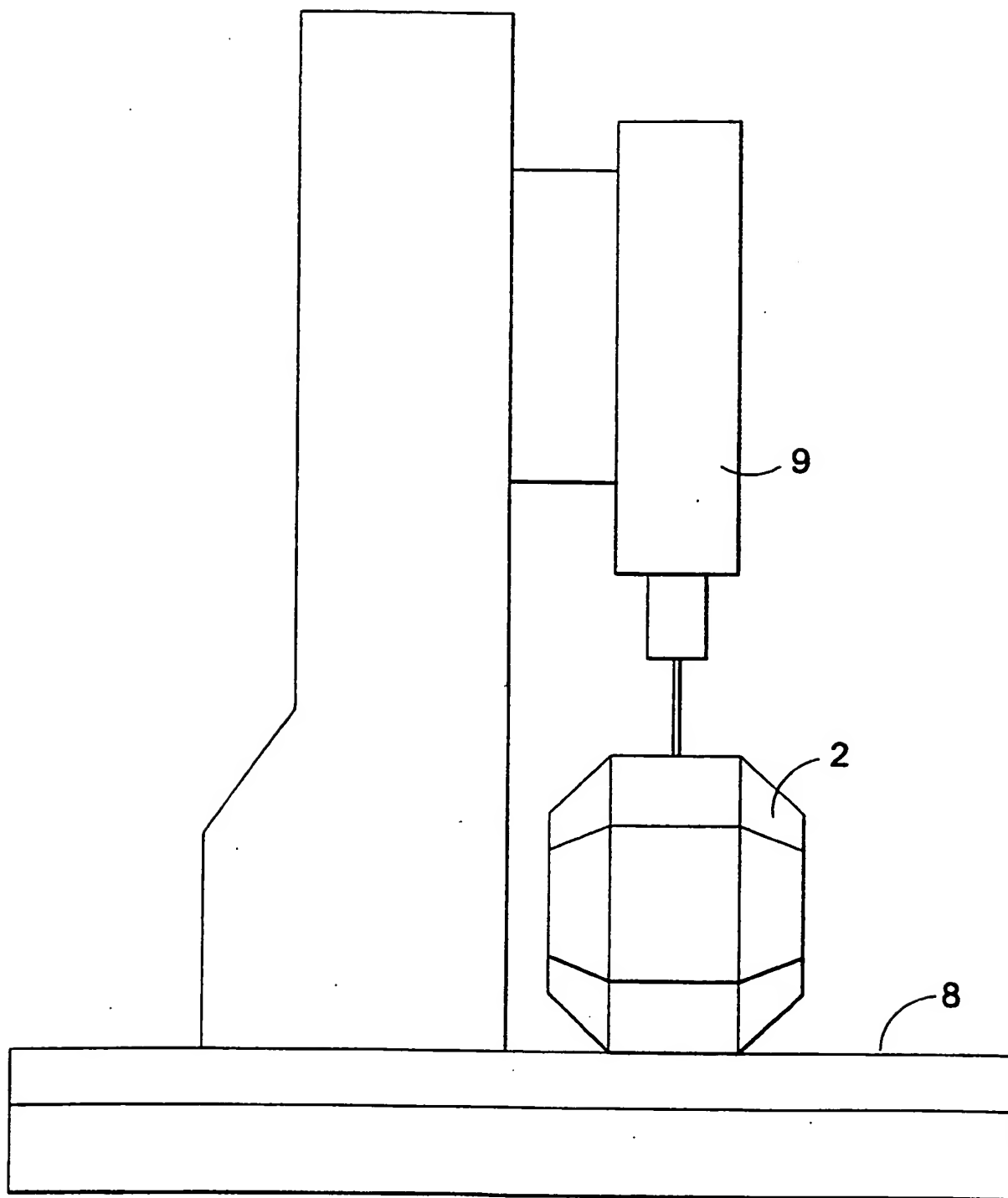


Fig.5

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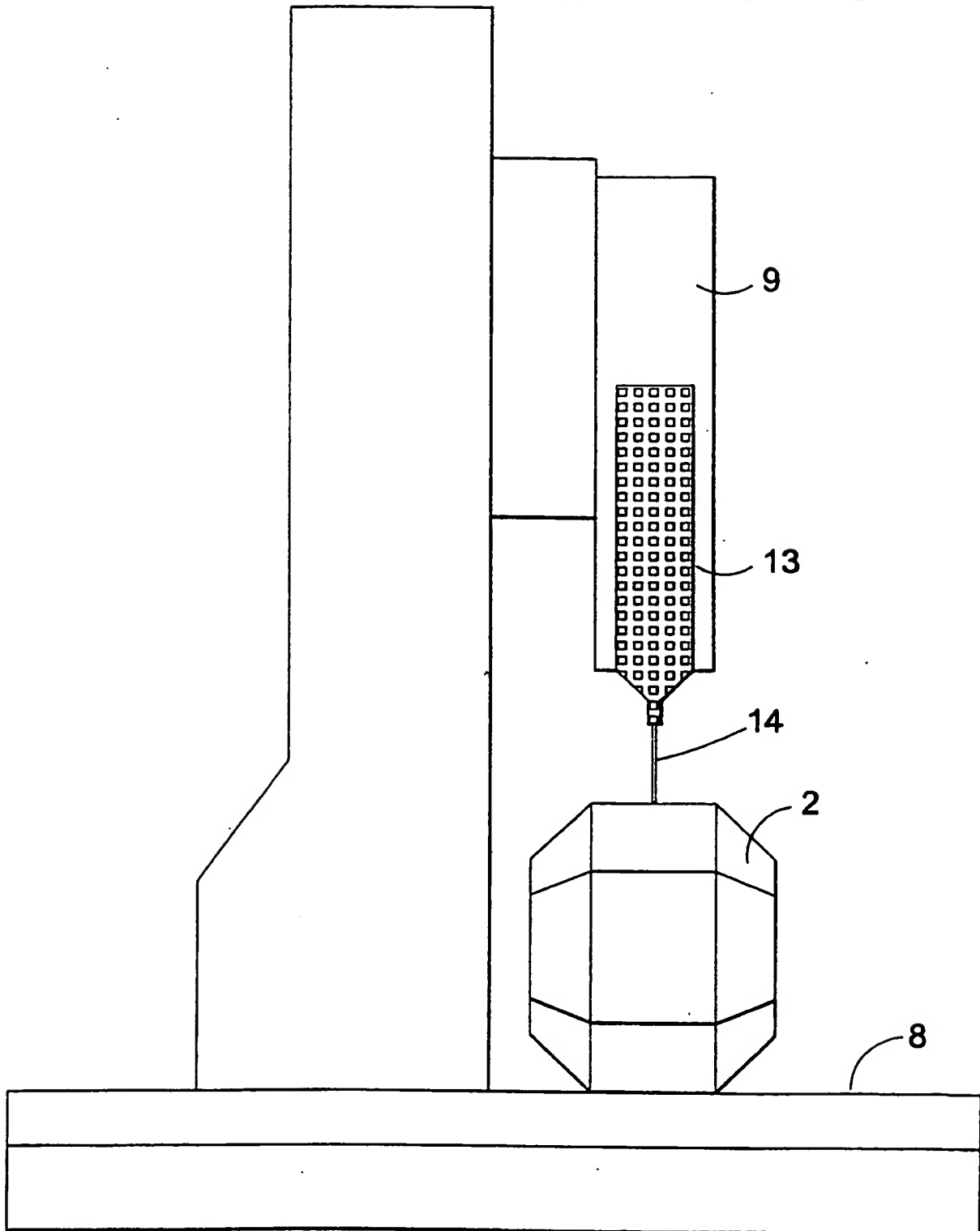
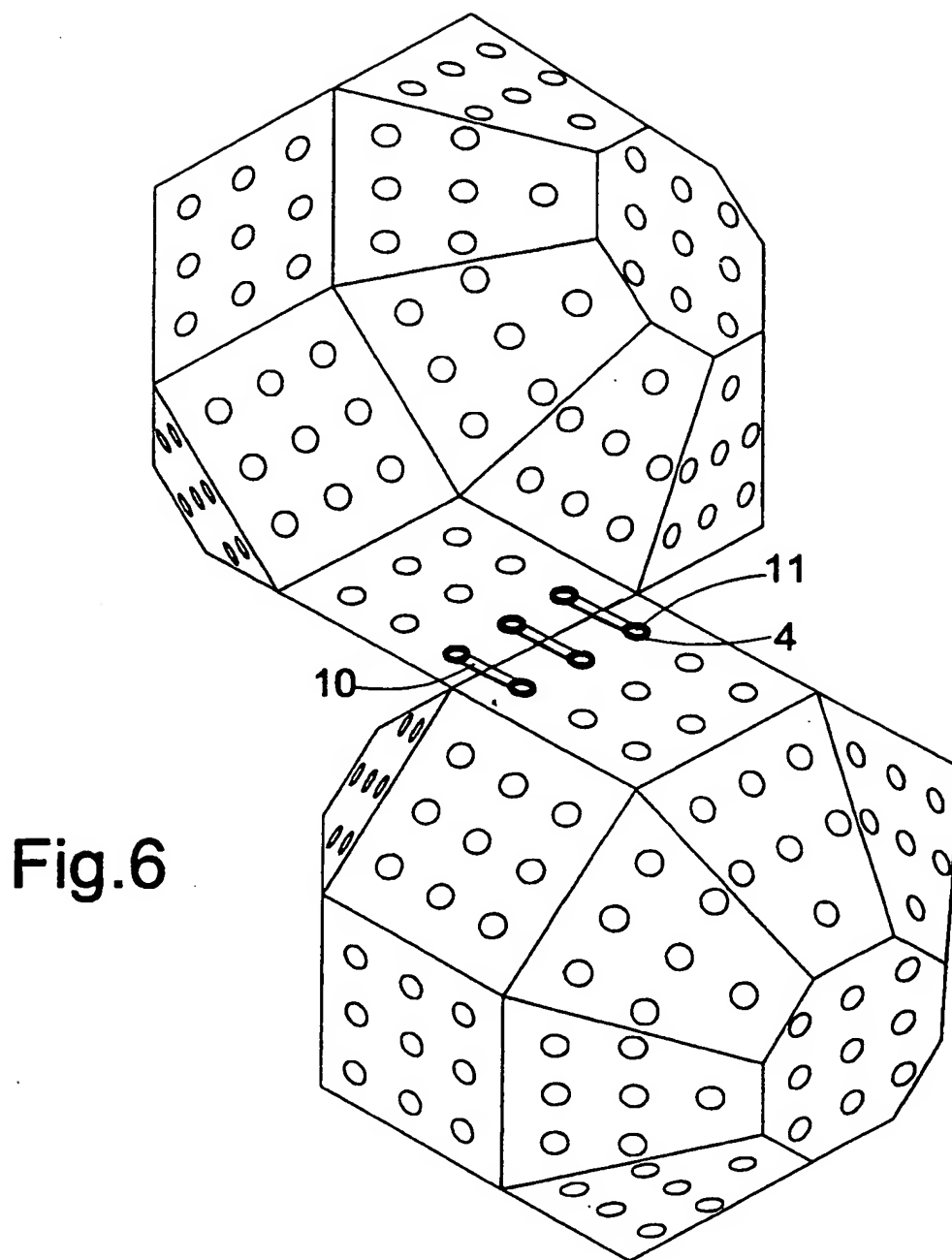


Fig.5a

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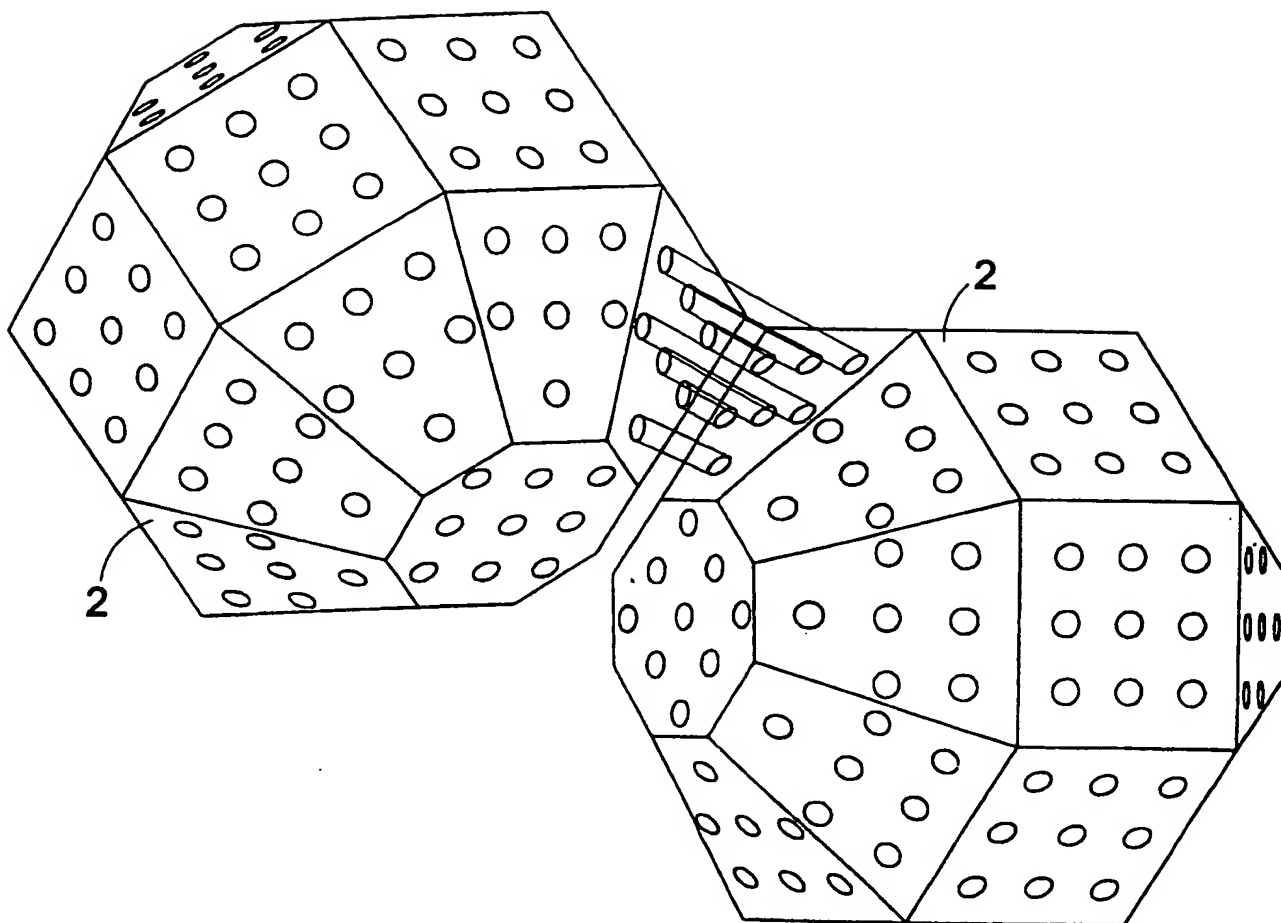


Fig.7

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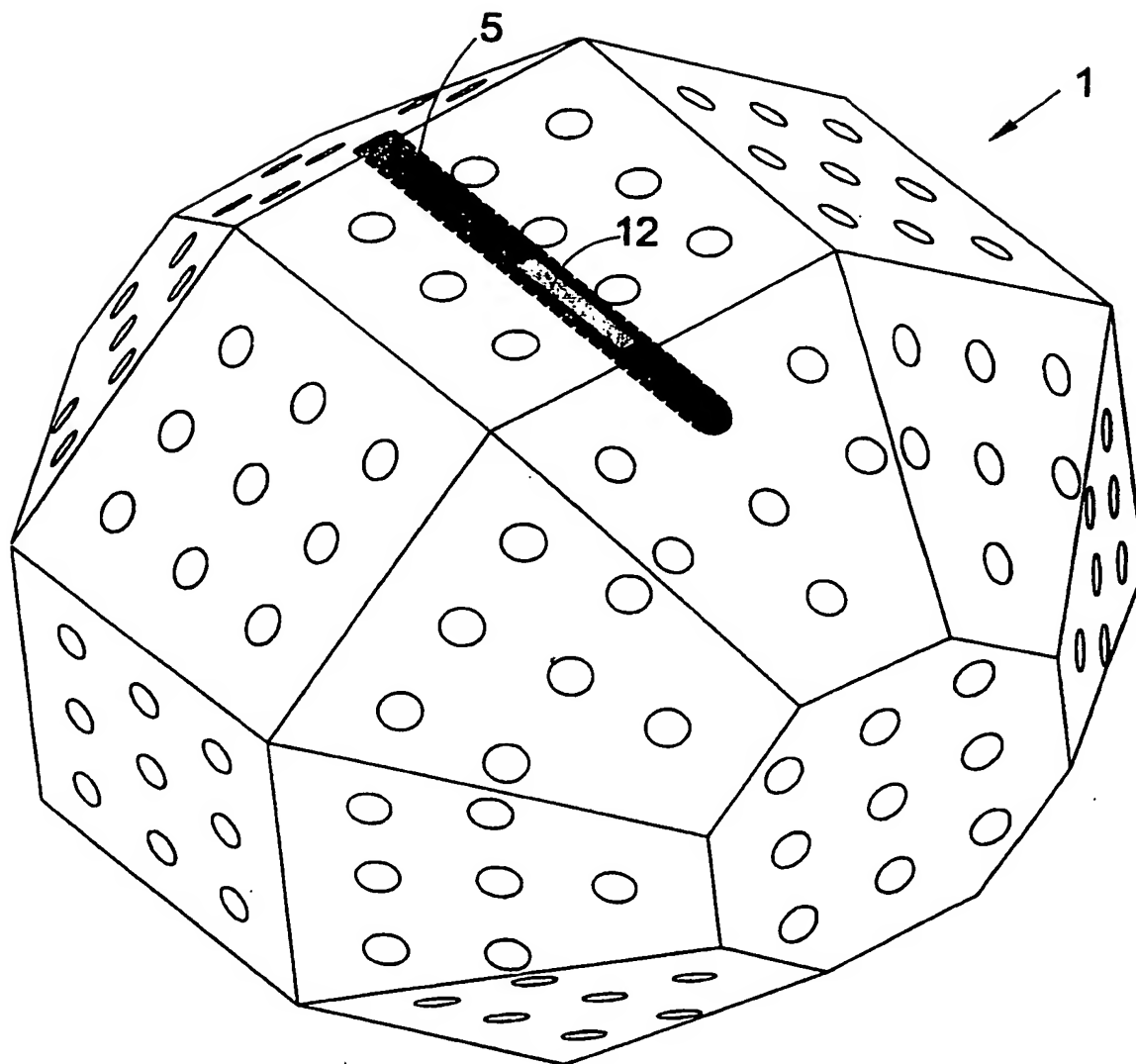


Fig.8

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/04610

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H05K1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H05K H01L H01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 016, no. 352 (E-1241), 29 July 1992 (1992-07-29) -& JP 04 107989 A (HITACHI DENSHI LTD), 9 April 1992 (1992-04-09) abstract	1,3-6,9, 12,13, 16, 19-22,25
Y	---	2,7,8, 11,23, 27,28
Y	US 5 191 709 A (KAWAKAMI ET AL.) 9 March 1993 (1993-03-09) abstract	2,11,27, 28
A	US 5 909 012 A (TODD ET AL.) 1 June 1999 (1999-06-01) claims; figures	1,2,5,7, 8,14-17
Y	---	7,8,23
	--- -/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

22 February 2001

Date of mailing of the international search report

01/03/2001

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/04610

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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